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(54) **MICROPHONE AMPLIFIER CIRCUIT**

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H04R 3/00 (2006.01)
H04R 19/01 (2006.01)
H04R 3/06 (2006.01)

(52) **U.S. Cl.**
CPC ***H04R 3/00*** (2013.01); ***H04R 19/016*** (2013.01); *H04R 3/06* (2013.01); *H04R 2410/03* (2013.01)

(58) **Field of Classification Search**
CPC H04R 3/00; H04R 19/016; H04R 3/06; H04R 2410/03; H03G 5/00
USPC 381/104, 94.7, 95, 120, 113, 122
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0254544 A1		10/2010	Kimura et al.	
2011/0293115 A1*		12/2011	Henriksen	H03F 1/301 381/111
2013/0129117 A1*		5/2013	Thomsen	H04R 3/00 381/111

FOREIGN PATENT DOCUMENTS

EP	1 096 831	5/2001
JP	2001-102875	4/2001
JP	2008-153981	7/2008
JP	2010-245729	10/2010

* cited by examiner

Primary Examiner — Vivian Chin
Assistant Examiner — Ammar Hamid

(57) **ABSTRACT**

The invention provides a microphone amplifier circuit which enhances the SNR (signal noise ratio) and expands the dynamic range by reducing the noise level. A microphone amplifier circuit includes a preamplifier which amplifies an audio signal from a capacitor microphone, a level detection circuit which outputs a level detection signal when the level of the audio signal is in the vicinity of the noise level of the microphone amplifier circuit, and an attenuator which attenuates the level of the audio signal outputted from the preamplifier in response to the level detection signal. The preamplifier includes an operational amplifier, a feedback capacitor and a feedback resistor.

20 Claims, 4 Drawing Sheets

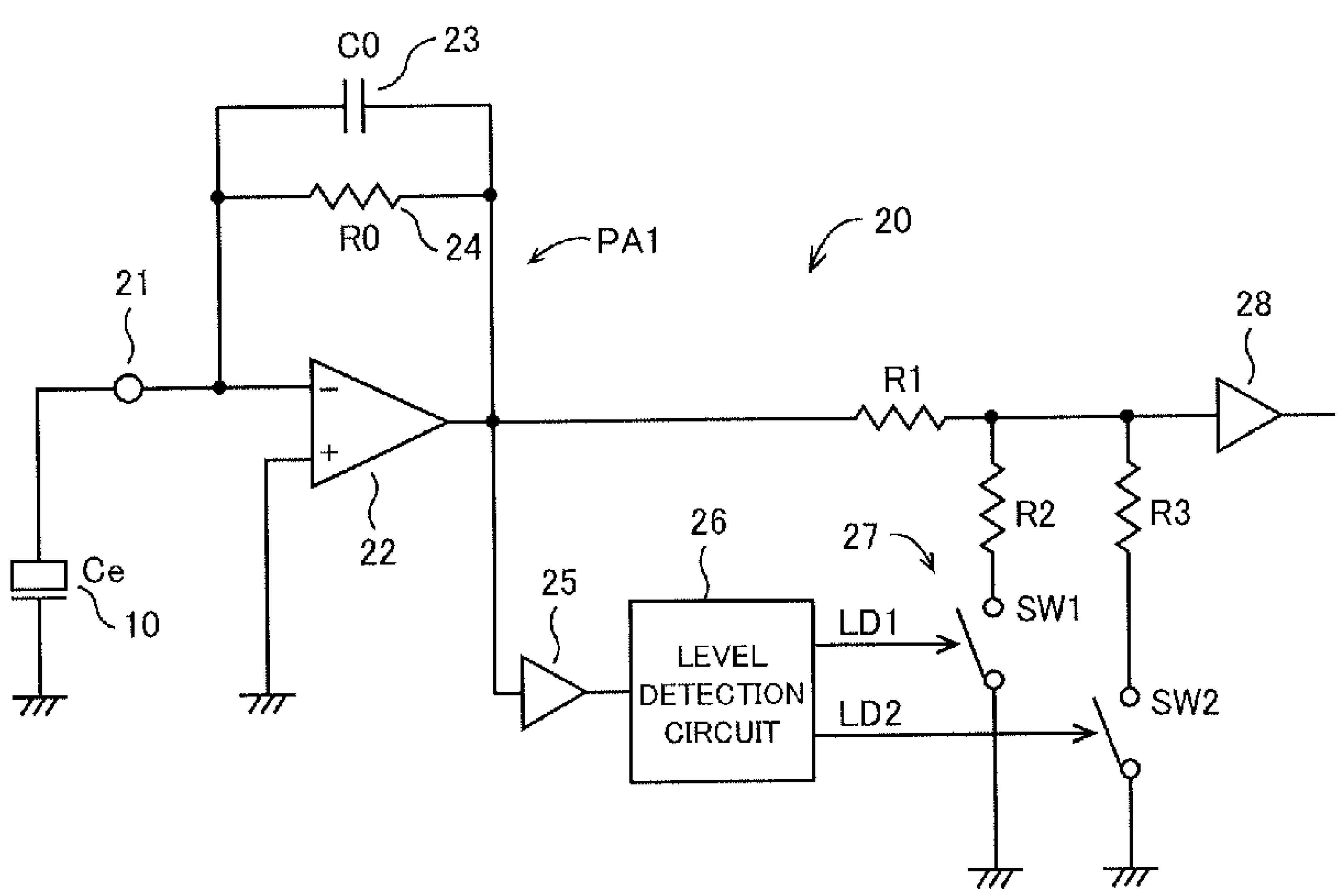


FIG.1

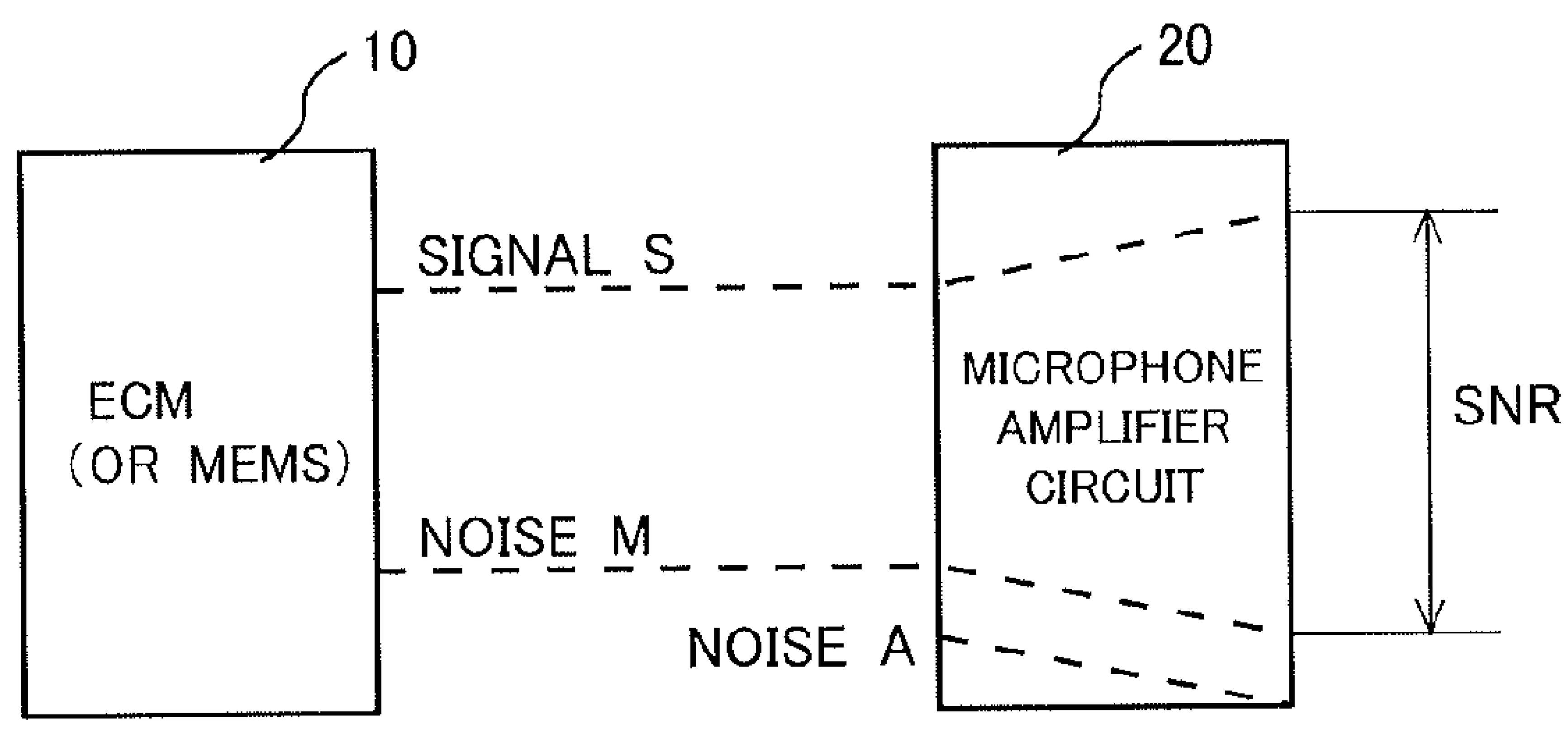

10
20
ECM
(OR MEMS)
SIGNAL S
NOISE M
NOISE A
MICROPHONE
AMPLIFIER
CIRCUIT
SNR

FIG.2

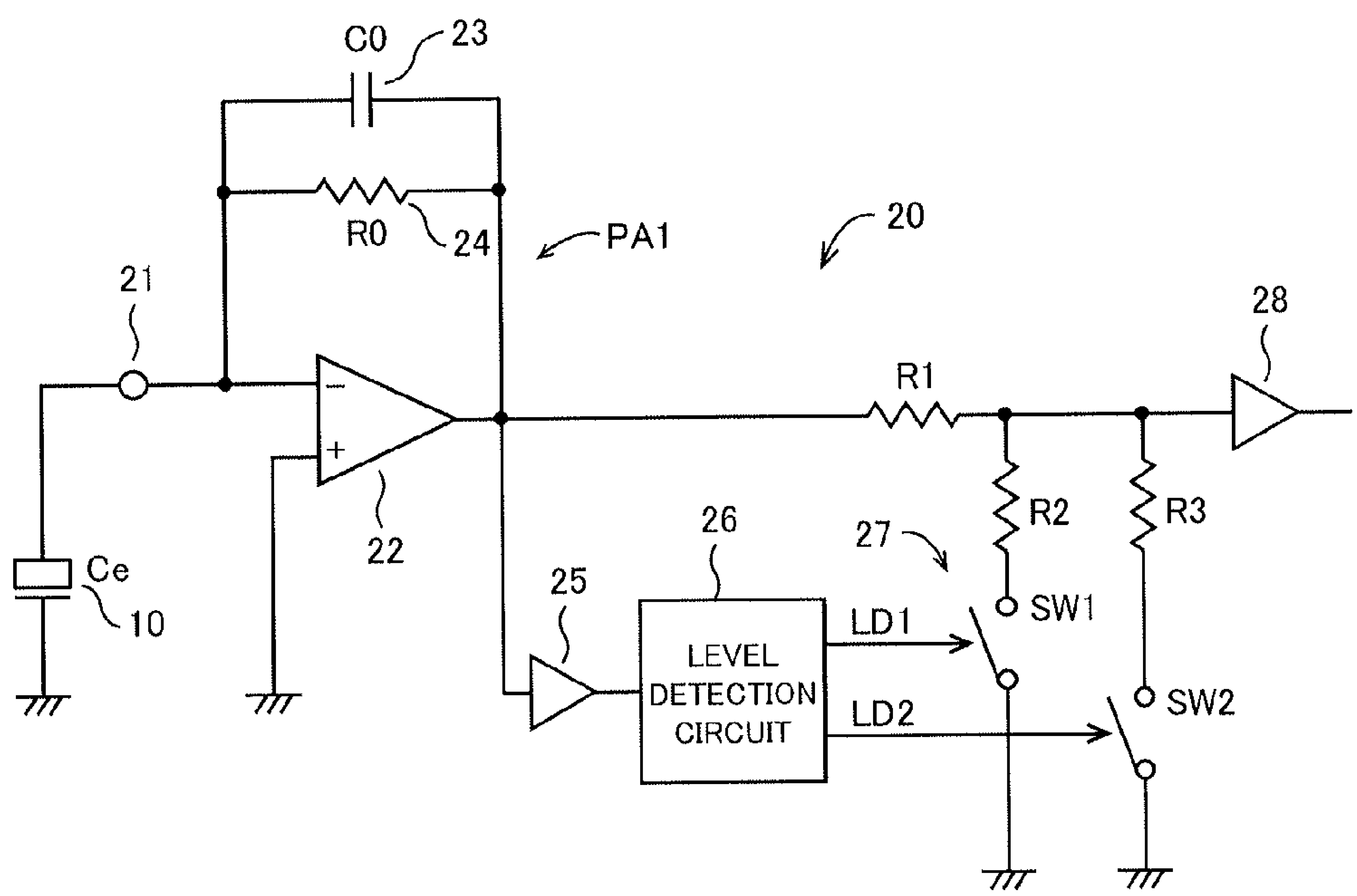
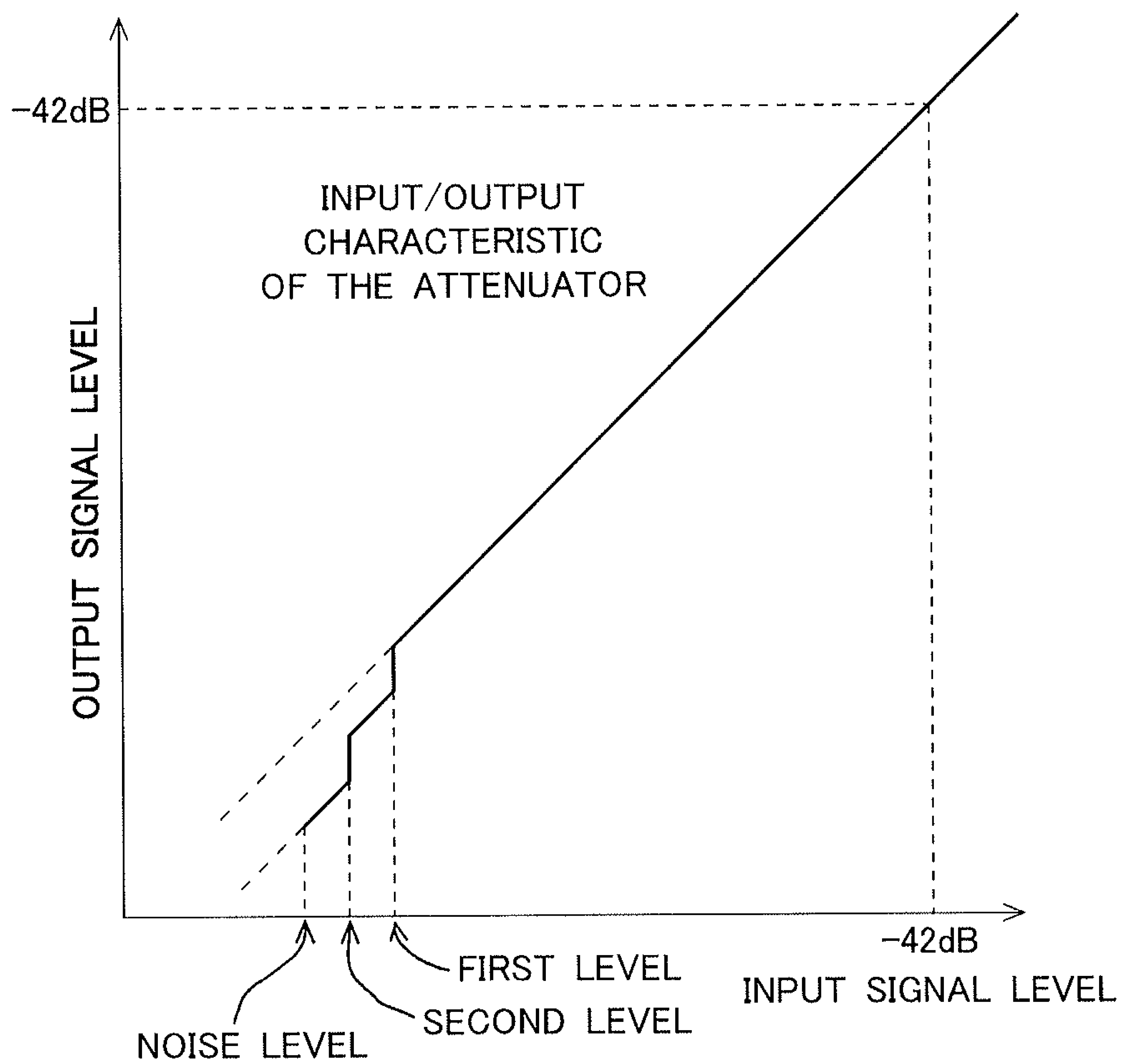

C0
23
R0
24
PA1
20
21
28
R1
R2
R3
22
Ce
10
25
26
27
LEVEL
DETECTION
CIRCUIT
LD1
LD2
SW1
SW2

FIG.3



−42dB
INPUT/OUTPUT CHARACTERISTIC OF THE ATTENUATOR
OUTPUT SIGNAL LEVEL
FIRST LEVEL
SECOND LEVEL
NOISE LEVEL
−42dB
INPUT SIGNAL LEVEL

FIG.4

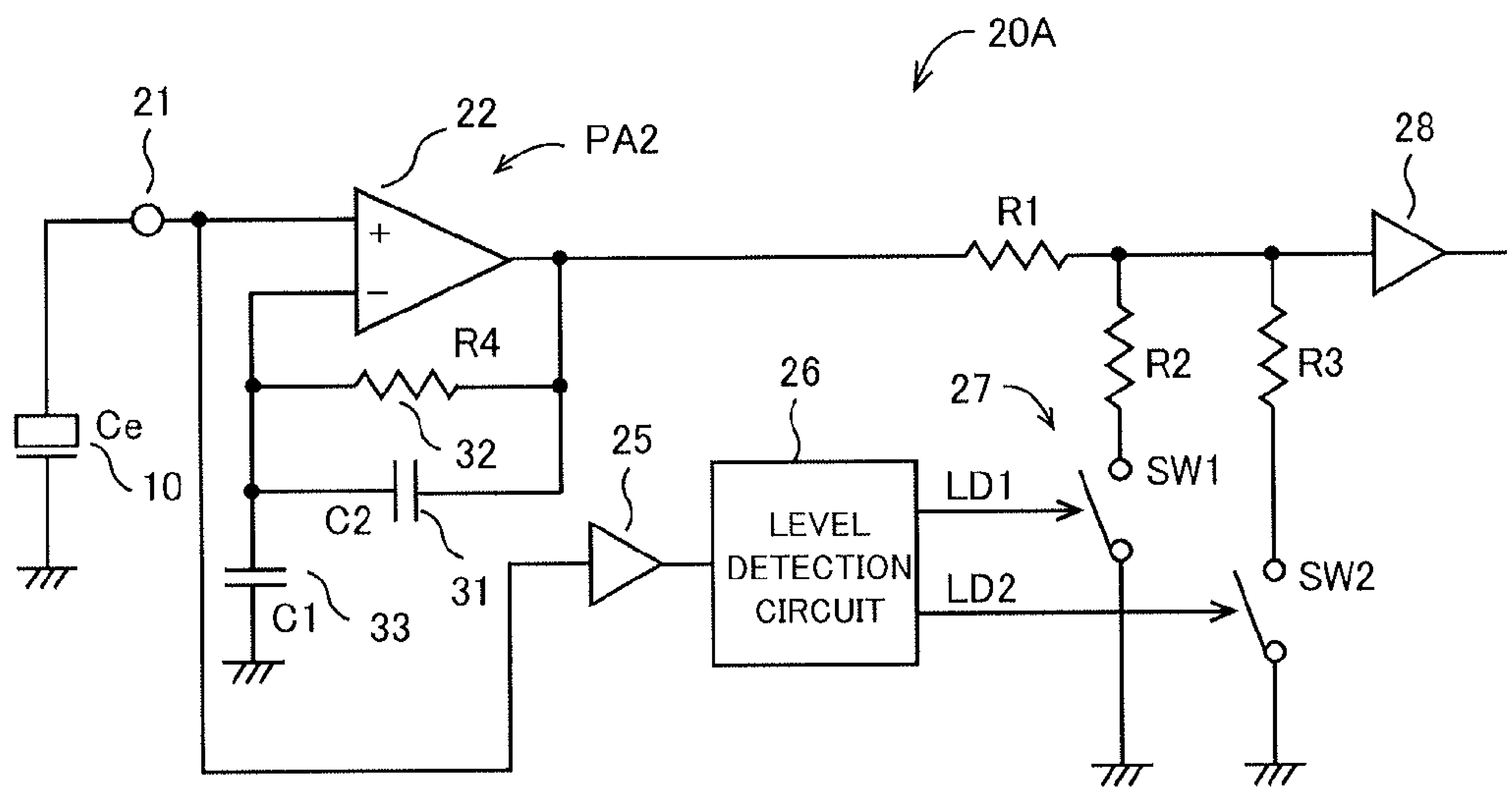

20A
21
22
PA2
R1
28
R4
Ce
10
32
C2
31
C1
33
25
26
LEVEL
DETECTION
CIRCUIT
LD1
LD2
27
R2
R3
SW1
SW2

FIG.5A

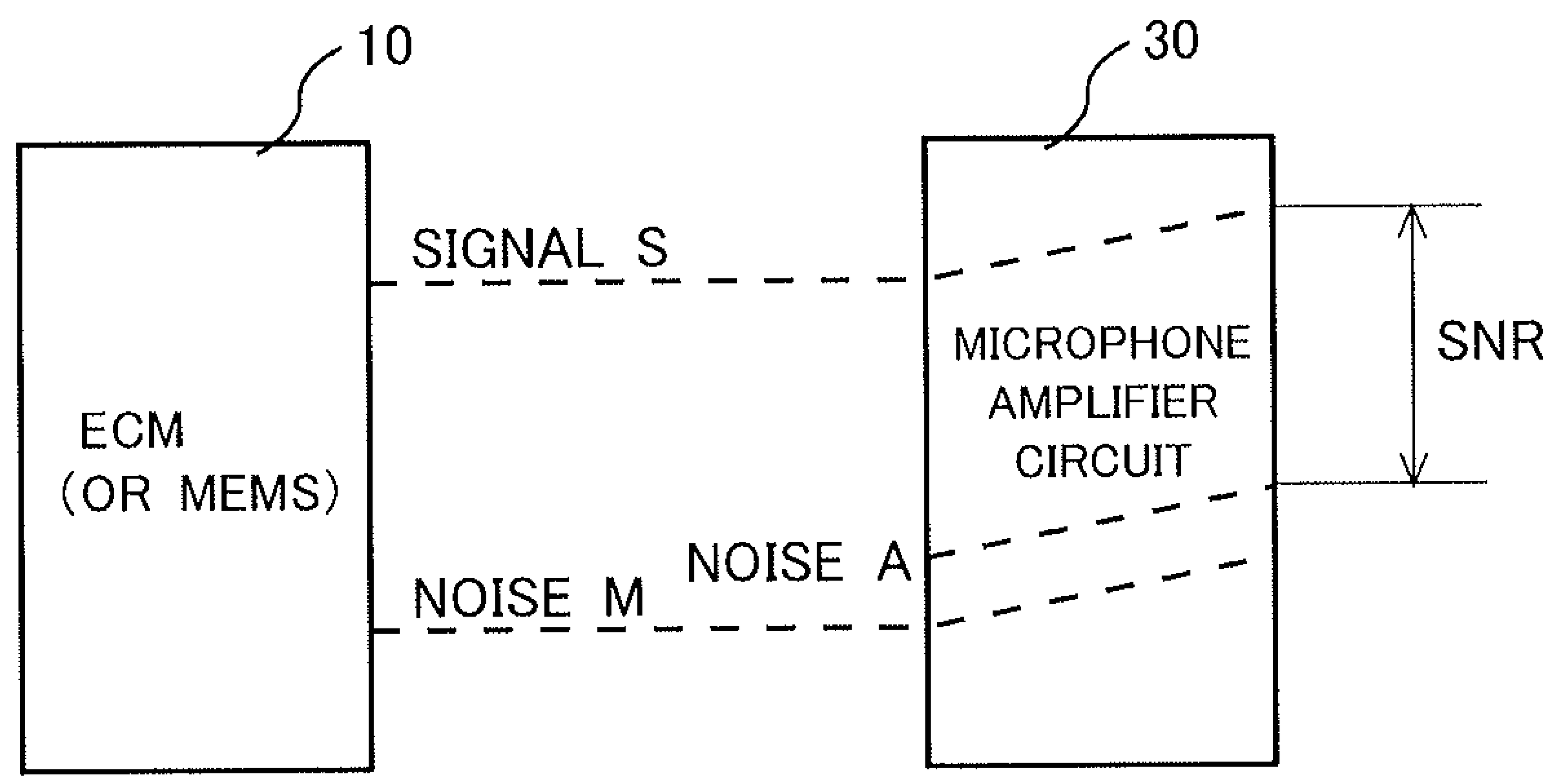
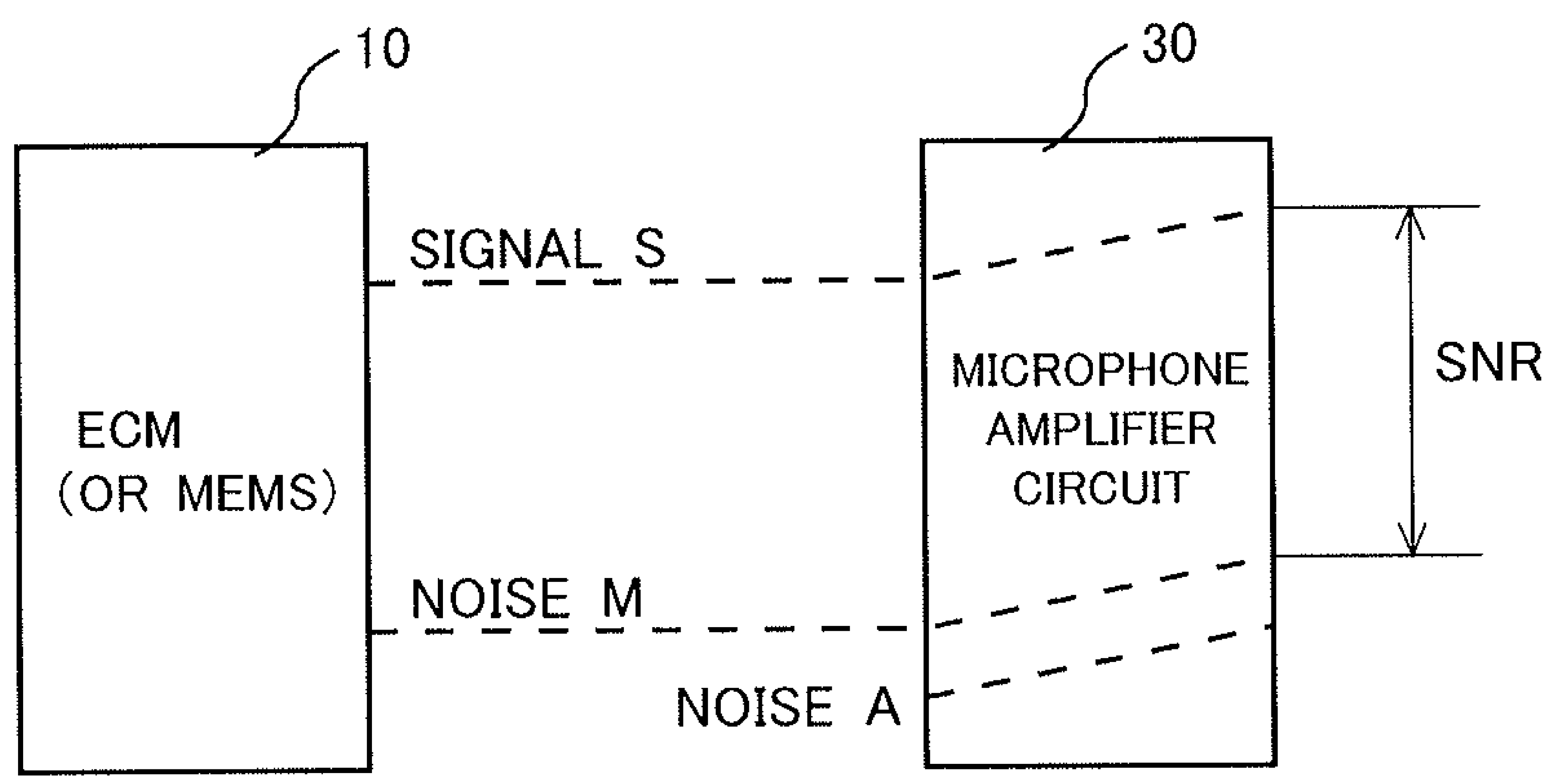

10
30
ECM
(OR MEMS)
SIGNAL S
NOISE M
NOISE A
MICROPHONE
AMPLIFIER
CIRCUIT
SNR

FIG.5B


10
30
ECM
(OR MEMS)
SIGNAL S
NOISE M
NOISE A
MICROPHONE
AMPLIFIER
CIRCUIT
SNR

MICROPHONE AMPLIFIER CIRCUIT

CROSS-REFERENCE OF THE INVENTION

This application claims priority from Japanese Patent Application No. 2012-151321, filed Jul. 5, 2012, the content of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a microphone amplifier circuit for a capacitor microphone.

2. Description of the Related Art

A MEMS microphone and an electret capacitor microphone (ECM) are known as a type of capacitor microphone.

The MEMS microphone is a capacitor including two electrode plates called a diaphragm and a back plate which face close to each other, and such a structure is formed on a silicon substrate by a MEMS (Micro Electro Mechanical Systems) technique. The MEMS microphone is resistant to the temperature of a standard solder reflow process, and is soldered on a printed board together with other components, for example.

In order to operate the MEMS microphone, a relatively high direct bias voltage is necessary. By applying this bias voltage, constant electric charge Q is charged in the capacitor forming the MEMS microphone. In this state, when the diaphragm vibrates by sound pressure, the electrostatic capacitance C of the capacitor changes to change voltage V between the terminals. The change of the voltage V is outputted as an audio signal.

On the other hand, the ECM uses an electret element which holds electric charge semipermanently and does not need a bias voltage.

A microphone amplifier circuit for a capacitor microphone is described in the Japanese Patent Application Publication Nos. 2010-245729, 2008-153981 and 2001-102875.

FIGS. **5**A and **5**B are conceptual diagrams showing the SNR (signal-noise ratio) characteristic of a conventional microphone amplifier circuit **30**. FIG. **5**A shows a case where the input conversion noise A of the microphone amplifier circuit **30** is larger than the noise M of a capacitor microphone **10** such as an ECM. In this case, the input conversion noise A is dominant as a noise source, and the SNR is the ratio of the audio signal S of the capacitor microphone **10** to the input conversion noise A which are amplified by the microphone amplifier circuit **30**.

FIG. **5**B shows a case where the input conversion noise A of the microphone amplifier circuit **30** is reduced to less than the noise M of the capacitor microphone **10**. In this case, the noise M of the capacitor microphone **10** is dominant as a noise source, and the SNR is the ratio of the audio signal S of the microphone element **10** to the noise M of the capacitor microphone **10** which are amplified by the microphone amplifier circuit **30**.

In other words, the noise of the microphone amplifier circuit **30** is determined by the larger of the input conversion noise A and the noise M of the capacitor microphone **10**. Then, even if the input conversion noise A of the microphone amplifier circuit **30** is reduced as much as possible, the enhancement of the SNR is limited by the noise M of the capacitor microphone **10**.

The invention is to provide a microphone amplifier circuit which enhances the SNR and expands the dynamic range of the microphone amplifier circuit.

SUMMARY OF THE INVENTION

A microphone amplifier circuit of the invention includes: a preamplifier amplifying an audio signal from a capacitor microphone; a level detection circuit outputting a level detection signal when a level of the audio signal is in a vicinity of a noise level of the microphone amplifier circuit; and an attenuator attenuating the level of the audio signal outputted from the preamplifier in response to the level detection signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a conceptual diagram showing the signal noise characteristic of a microphone amplifier circuit of the invention.

FIG. **2** is a circuit diagram of a microphone amplifier circuit in a first embodiment of the invention.

FIG. **3** is a graph showing the input output characteristic of an attenuator.

FIG. **4** is a circuit diagram of a microphone amplifier circuit in a second embodiment of the invention.

FIGS. **5**A and **5**B are conceptual diagrams showing the signal noise characteristic of a conventional microphone amplifier circuit.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a conceptual diagram showing the signal noise characteristic of a microphone amplifier circuit of the invention. An audio signal S and noise M from a capacitor microphone **10** such as an ECM or a MEMS microphone are amplified by a microphone amplifier circuit **20** and outputted.

The microphone amplifier circuit **20** has a control structure of controlling the gain of the microphone amplifier circuit **20** dynamically corresponding to the level of an audio signal S from the capacitor microphone **10**, and reduces the noise level by reducing the gain by the control structure only when the level of the audio signal S is on an ultralow level in the vicinity of the noise level of the microphone amplifier circuit **20** (in this case, in the vicinity of the level of the noise M). The gain when the level of the audio signal S is higher than the vicinity of the noise level, i.e., the gain when there is a signal is left as it is, thereby resulting in the enhancement of the SNR and the dynamic range.

In this case, the SNR is defined as the ratio of the reference level of the audio signal S to the noise level when there is not a signal. That is, in the invention, the noise level differs between when there is a signal and when there is not a signal.

FIG. **1** shows a case where the input conversion noise A of the microphone amplifier circuit **20** is reduced to less than the noise M of the capacitor microphone **10** and the noise M is dominant. However, the concept is also applicable to the contrary case wherein the input conversion noise A of the microphone amplifier circuit **20** is dominant. In other words, in this case, the noise level of the microphone amplifier **20** is determined by the input conversion noise A.

First Embodiment

FIG. **2** is a circuit diagram of the microphone amplifier circuit **20** formed corresponding to the fundamental concept described above. The capacitor microphone **10** is connected to the inversion input terminal (−) of an operational amplifier **22** through a terminal **21** of the IC. The non-inversion input terminal (+) of the operational amplifier **22** is grounded. A capacitor **23** and a feedback resistor **24** are connected in parallel between the output terminal and the inversion input terminal (−) of the operational amplifier **22**. The operational amplifier **22**, the feedback capacitor **23** and the feedback resistor **24** form a preamplifier PA**1**.

The feedback resistor **24** is provided so as to stabilize the potential of the output terminal and the inversion input terminal (−) of the operational amplifier **22**. In order to prevent an audio signal from the capacitor microphone **10** from passing from the inversion input terminal (−) to the output terminal of the operational amplifier **22** through the feedback resistor **24**, the resistance value R0 of the feedback resistor **24** is set to an enough large value. When the resistance value R0 of the feedback resistor **24** is large enough, the gain of the preamplifier PA**1** is Ce/C0. Ce is the capacitance of the capacitor microphone **10**, and C0 is the capacitance of the feedback capacitor **23**. The gain may be set to 1 or more, or set to 1 or less by the ratio of Ce/C0.

An audio signal amplified by the preamplifier PA**1** is inputted to a level detection circuit **26** through an amplifier **25**. The level detection circuit **26** outputs a first level detection signal LD**1** when the level of the audio signal amplified by the preamplifier PA**1** is lower than a first level which is in the vicinity of the noise level and higher than the noise level, and outputs a second detection signal LD**2** when the level of the audio signal is lower than a second level which is higher than the noise level and lower than the first level. In this case, the noise level means the level of the larger of the input conversion noise A and the noise M of the capacitor microphone **10** as described above. The vicinity of the noise level is defined as a range between the noise level and the level higher than the noise level by 16 dB. It is preferable to set the first level to higher than the noise level by a range of 10 dB to 16 dB. It is preferable to set the second level to a range between the noise level and the first level. It is more preferable to set the second level to lower than the first level by 3 dB to 6 dB.

An attenuator **27** is provided on the stage next to the preamplifier PA**1**, and this is a circuit which attenuates the level of the audio signal outputted from the preamplifier PA**1** in response to the first level detection signal LD**1** and attenuates the level of the signal outputted from the preamplifier PA**1** more largely in response to the second level detection signal LD**2**.

The attenuator **27** includes a first resistor R1 of which one end is connected to the output terminal of the preamplifier PA**1**, a second resistor R2 and a first switching element SW1 connected in series between the other end of the first resistor R1 and the ground, and a third resistor R3 and a second switching element SW2 connected in series between the other end of the first resistor R1 and the ground. The first switching element SW1 turns on in response to the first level detection signal LD**1**, and the second switching element SW2 turns on in response to the second level detection signal LD**2**. The audio signal passing through the attenuator **27** is outputted through a buffer **28**. The first and second switching elements SW1, SW2 can be made of a MOS transistor or a bipolar transistor.

FIG. **3** is a graph showing the input output characteristic of the attenuator **27**. In this case, the input signal level of the attenuator **27** is the level of an audio signal outputted from the preamplifier PA**1**. As shown in FIG. **3**, when the level of the audio signal is higher than the first level, the first and second level detection signals LD**1**, LD**2** are not outputted and the first and second switching elements SW1, SW2 turn off Therefore, the audio signal outputted from the preamplifier PA**1** is outputted without attenuated. When the level of the audio signal becomes lower than the first level, the first level detection signal LD**1** is outputted and the first switching element SW1 turns on in response to this. The second resistor R2 is then grounded through the conductive first switching element SW1, and thus the audio signal is attenuated.

When the audio signal level becomes lower than the second level, the second level detection signal LD**2** as well as the first level detection signal LD**1** is outputted, and the first and second switching elements SW1, SW2 turn on in response to these. Then the second resistor R2 and the third resistor R3 are grounded through the conductive first and second switching elements SW1, SW2, and thus the audio signal is attenuated more largely. The attenuation amount of the audio signal is adjustable by the resistance values of the second resistor R2 and the third resistor R3.

In this manner, only when the level of the audio signal is on an ultralow level in the vicinity of the noise level of the microphone amplifier circuit **20**, the noise level is reduced by reducing the gain of the preamplifier PA**1** by the attenuator **27**. The gain when the level of the audio signal is higher than the first level, i.e., the gain when there is a signal is left as it is, thereby resulting in the enhancement of the SNR and the expansion of the dynamic range of the microphone amplifier circuit **20**.

While the attenuator **27** performs a two-stage gain control using the first and second detection signals LD**1**, LD**2** of the level detection circuit **26**, the attenuator **27** may perform a one-stage gain control using only the first detection signal LD**1** of the level detection circuit **26**. In this case, the second resistor R3 and the second switching element SW2 of the attenuator **27** are omitted.

Furthermore, by increasing the number of the detection signals of the level detection circuit **26**, the attenuator **27** may perform a three or more stage gain control. In this case, in the attenuator **27**, the number of the switching elements and resistors connected in series is increased or decreased corresponding to the increase or decrease of the detection signals. By increasing the number of the gain control stages, the unnaturalness of audio due to the gain control is moderated.

Second Embodiment

FIG. **4** is a circuit diagram of a microphone amplifier circuit **20**A in a second embodiment. In this microphone amplifier circuit **20**A, an audio signal from the capacitor microphone **10** is inputted to the level detection circuit **26** without through a preamplifier PA**2**. Therefore, the level detection circuit **26** detects the level of the audio signal outputted from the capacitor microphone **10** which is not amplified by the preamplifier PA**2** yet.

In this case, the capacitor microphone **10** is connected to the non-inversion input terminal (+) of the operational amplifier **22** through the terminal **21** of the IC. The inversion input terminal (−) is grounded through a first capacitor **33**. A second capacitor **31** and a feedback resistor **32** are connected in parallel between the output terminal and the inversion input terminal (−) of the operational amplifier **22**.

The resistance value R4 of the feedback resistor **32** is set to an enough large value from the same reason as the reason for the circuit of the first embodiment. When the resistance value R4 of the feedback resistor **32** is large enough, the gain of the preamplifier PA**2** is (1+C1/C2). C1 is the capacitance of the first capacitor **33**, and C2 is the capacitance of the second capacitor **31**. The other structure is the same as that of the first embodiment.

In the second embodiment, too, only when the level of an audio signal is on an ultralow level in the vicinity of the noise level of the microphone amplifier circuit **20**A, the noise level is reduced by reducing the gain of the preamplifier PA**2** by the attenuator **27**, thereby enhancing the SNR and expanding the dynamic range of the microphone amplifier circuit **20**A.

A microphone amplifier circuit of the invention enhances the SNR and expands the dynamic range since the level of an audio signal outputted from the preamplifier is attenuated only when the level of the audio signal is in the vicinity of the noise level of the microphone amplifier circuit.

What is claimed is:

1. A microphone amplifier circuit comprising:

a preamplifier amplifying an audio signal from a capacitor microphone and having a predetermined gain, wherein the preamplifier comprises an operational amplifier having a first capacitor and a feedback resistor each coupled between an output terminal and an input terminal of the operational amplifier to set a gain thereof;

a level detection circuit having an input coupled to one of the audio signal and an output of the preamplifier and outputting a level detection signal when a level of the audio signal is in a vicinity of a noise level of the microphone amplifier circuit; and

an attenuator attenuating the level of the audio signal outputted from the preamplifier in amounts varying in response to a state of the level detection signal.

2. The microphone amplifier for claim **1**, wherein the attenuator comprises a first resistor having one end connected to an output terminal of the preamplifier and comprises a second resistor and a switching element that are connected in series between another end of the first resistor and a ground, wherein the switching element turns on in response to the level detection signal.

3. The microphone amplifier circuit of claim **1**, wherein the level detection circuit detects the level of the audio signal which is amplified by the preamplifier.

4. The microphone amplifier circuit of claim **1**, wherein the level detection circuit detects the level of the audio signal which is not amplified by the preamplifier.

5. The microphone amplifier circuit of claim **1**, wherein the preamplifier comprises the operational amplifier comprising an inversion input terminal, a non-inversion input terminal and an output terminal, and comprises the first capacitor and the feedback resistor connected in parallel between the output terminal and the inversion input terminal, wherein the capacitor microphone is connected to the inversion input terminal, the non-inversion input terminal is grounded, and an output of the operational amplifier is inputted to the level detection circuit.

6. The microphone amplifier circuit of claim **1**, wherein the preamplifier comprises the operational amplifier comprising an inversion input terminal, a non-inversion input terminal and an output terminal, and comprises a second capacitor connected between the inversion input terminal and a ground, and comprises the first capacitor and the feedback resistor that are connected in parallel between the output terminal and the inversion input terminal, wherein the capacitor microphone is connected to the non-inversion input terminal and an output of the capacitor microphone is inputted to the level detection circuit.

7. The microphone amplifier circuit of claim **1**, wherein the capacitor microphone comprises a MEMS microphone.

8. The microphone amplifier circuit of claim **1**, wherein the capacitor microphone comprises an electret capacitor microphone.

9. A microphone amplifier circuit comprising:

a preamplifier amplifying an audio signal from a capacitor microphone and having a predetermined gain, wherein the preamplifier comprises an operational amplifier having a first capacitor and a feedback resistor each coupled between an output terminal and an input terminal of the operational amplifier to set a gain thereof;

a level detection circuit having an input coupled to one of the audio signal and an output of the preamplifier and outputting a first level detection signal when a level of the audio signal is lower than a first level which is in a vicinity of a noise level of the microphone amplifier circuit and higher than the noise level, and outputting a second level detection signal when the level of the audio signal is lower than a second level which is higher than the noise level and lower than the first level; and

an attenuator attenuating the level of the audio signal outputted from the preamplifier by a first amount in response to the first level detection signal, and attenuating the level of the signal outputted from the preamplifier by a second amount larger than the first amount in response to the second level detection signal.

10. The microphone amplifier circuit of claim **9**, wherein the attenuator comprises a first resistor having one end connected to an output terminal of the preamplifier, comprises a second resistor and a first switching element that are connected in series between another end of the first resistor and a ground, and comprises a third resistor and a second switching element that connected in series between the another end of the first resistor and the ground, wherein the first switching element turns on in response to the first level detection signal, and the second switching element turns on in response to the second level detection signal.

11. The microphone amplifier circuit of claim **9**, wherein the level detection circuit detects the level of the audio signal which is amplified by the preamplifier.

12. The microphone amplifier circuit of claim **9**, wherein the level detection circuit detects the level of the audio signal which is not amplified by the preamplifier.

13. The microphone amplifier circuit of claim **11**, wherein the preamplifier comprises the operational amplifier comprising an inversion input terminal, a non-inversion input terminal and an output terminal, and comprises the first capacitor and the feedback resistor connected in parallel between the output terminal and the inversion input terminal, wherein the capacitor microphone is connected to the inversion input terminal, the non-inversion input terminal is grounded, and an output of the operational amplifier is inputted to the level detection circuit.

14. The microphone amplifier circuit of claim **12**, wherein the preamplifier comprises the operational amplifier comprising an inversion input terminal, a non-inversion input terminal and an output terminal, and comprises a second capacitor connected between the inversion input terminal and a ground, and comprises the first capacitor and the feedback resistor that are connected in parallel between the output terminal and the inversion input terminal, wherein the capacitor microphone is connected to the non-inversion input terminal, and an output of the capacitor microphone is inputted to the level detection circuit.

15. The microphone amplifier circuit of claim **9**, wherein the capacitor microphone comprises a MEMS microphone.

16. The microphone amplifier circuit of claim **9**, wherein the capacitor microphone comprises an electret capacitor microphone.

17. A microphone amplifier circuit comprising:

a first amplifier amplifying an audio signal from a capacitor microphone and having a predetermined gain, wherein the first amplifier comprises an operational amplifier having a first capacitor and a feedback resistor each coupled between an output terminal and an input terminal of the operational amplifier to set a gain thereof;

a second amplifier further amplifying one of the audio signal and an output of the first amplifier;

a level detection circuit inputted with the audio signal amplified by the second amplifier and outputting a level detection signal when a level of the audio signal is in a vicinity of a noise level of the microphone amplifier circuit; and

an attenuator attenuating the level of the audio signal outputted from the first amplifier in amounts varying in response to a state of the level detection signal.

18. The microphone amplifier circuit of claim **17**, wherein the attenuator comprises a first resistor having one end connected to an output terminal of the first amplifier, and comprises a second resistor and a switching element that are connected in series between another end of the first resistor and a ground, wherein the switching element turns on in response to the level detection signal.

19. The microphone amplifier circuit of claim **17**, wherein the first amplifier comprises the operational amplifier comprising an inversion input terminal, a non-inversion input terminal and an output terminal, and comprises the first capacitor and the feedback resistor connected in parallel between the output terminal and the inversion input terminal, wherein the capacitor microphone is connected to the inversion input terminal, the non-inversion input terminal is grounded, and an output of the operational amplifier is inputted to the second amplifier.

20. The microphone amplifier circuit of claim **17**, wherein the capacitor microphone comprises a MEMS microphone or an electret capacitor microphone.

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